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(54) QUIET SPUR GEARS

(71) I, ENAKICHI HAYASAKA, a Japanese subject of 543-1 Ogikubo, Odawara-shi, Kanagawa-ken, Japan, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:

This invention relates to spur gears.

Noise produced from engaging gears constitutes a complete energy loss. Heretofore only the improvement of grinding accuracy in making gears has been said to be effective to prevent noise. It has been necessary, therefore, that a gear wheel has sufficient rigidity for maintaining any given point on a true circle during rotation of the gear wheel and, the tooth shape properly adjusted.

The thrust acting along the path of contact at the pressure angle formed when drive is transmitted to a cantilevered gear wheel results in distortion of the shaft in bending. In addition it is not easy to set up the gear wheel centre accurately. Further it is overlooked that the gear wheels in a gear train may not be in proper engagement, that is, the centre of the gear teeth may be eccentric with respect to the centre of rotation of the wheel. Thus it is obvious that there is a large possibility of the duplication of positive and negative centring errors and leading to quadrupling of errors between two engaged gear wheels. It is useless, therefore, to attach an excessive importance to grinding accuracy in making gears.

The present invention seeks to provide quiet spur gears. In such gears, energy may be prevented from being converted to and dissipated as noise energy thereby enhancing the transmission efficiency, the lifetime and the strength of the gears.

According to the invention there is provided a spur gear wheel comprising a flexible gear ring mounted with limited radial, limited axial and limited circumferential clearance on a rotatable holder in a groove therein. A gear wheel according to the invention when incorporated in a gear train compensates for centring errors of the gear wheels as rotary bodies, as the rotary centre of the gear wheel can move to a limited extent.

In order that the invention may be more readily understood specific embodiments thereof will now be described with reference to the accompanying drawings, in which:—

Figure 1 shows an assembly side view of a spur gear wheel according to the invention with a ring gear having laterally extending splines,

Figure 2 shows a broken section on the line II–II of Figure 1,

Figure 3 shows a side view indicating the structure of the gear ring of Figure 1,

Figure 4 shows a section on the line IV–IV of Figure 3,

Figure 5 shows a side view of a pitch circle diameter retaining plate for the gear wheel of Figure 1,

Figure 6 shows a section on the line VI–VI of Figure 5,

Figure 7 shows a side view of a boss for the gear wheel of Figure 1,

Figure 8 shows a section on the line VIII–VIII of the boss of Figure 7,

Figure 9 shows an assembly side view of a spur gear wheel according to the invention with a ring gear having internal splines,

Figure 10 shows broken section on the line X–X of Figure 9,

Figure 11 shows a side view of the structure of the gear ring of Figure 9,

Figure 12 is a section on the line XII–XII of Figure 11,

Figure 13 shows a side view of the splined boss for the gear wheel of Figure 9,

Figure 14 shows a broken section on the line XIV–XIV of Figure 13,

Figure 15 shows an assembly view of a spur gear wheel according to the invention with a flat rim gear ring,

Figure 16 shows a broken section on the line XVI–XVI of Figure 15,

Figure 17 shows a side view of the flat rim gear ring of Figure 15,

Figure 18 shows a section on the line

XVIII–XVIII of Figure 17,

Figure 19 shows a side view of a pitch circle diameter retaining plate for the gear wheel of Figure 15,

Figure 20 shows a section on the line XX–XX of Figure 19,

Figure 21 shows a side view of a boss part for the gear wheel of Figure 15,

Figure 22 shows a section on the line XXII–XXII of Figure 21,

Figure 23 shows an assembly side view of a spur gear wheel according to the invention with a gear ring having internally cut teeth and laterally extending splines,

Figure 24 shows a broken section on the line XXIV–XXIV of Figure 24,

Figure 25 shows a side view of the ring gear of Figure 23,

Figure 26 shows a section on the line XXVI–XXVI of Figure 25,

Figure 27 shows a side view of a pitch circle diameter retaining plate for the gear wheel of Figure 23,

Figure 28 shows a section on the line XXVIII–XXVIII of Figure 27,

Figure 29 shows an assembly side view of a spur gear wheel according to the invention with a gear ring having internally cut teeth and external circumferential splines,

Figure 30 shows a broken section on the line XXX–XXX of Figure 29,

Figure 31 shows a side view of the gear ring of Figure 29,

Figure 32 shows a section on the line XXXII–XXXII of Figure 31,

Figure 33 shows a pitch circle diameter retaining plate for the gear wheel of Figure 29,

Figure 34 shows a section on the line XXXIV–XXXIV of Figure 34,

Figure 35 shows a side view of a gear wheel which holds pitch circle diameter accurately and of which discs of 1 module or so in thickness are fixed on the both sides,

Figure 36 shows a section on the line XXXVI–XXXVI of Figure 35,

Figures 37 to 40 show various gear trains incorporating spur gears according to the invention,

Figures 41 and 42 are descriptive drawings of the elastic running of a gear ring, and

Figure 43 is a descriptive drawing of the elastic running of a gear ring in a large-load process.

The illustrated gear wheels have gear rings having a rim carrying gear teeth. The rings are manufactured independently with the thickness thereof restricted so that the gear teeth, treated with a material having an elasticity, have a sufficient strength to stand maximum bending moment active thereon. The embodiments of the invention are shown in Figs. 3, 4, 11-12, 17-18, 25-26, 31-32.

The structural drawings shown in the other embodiment drawings show construction of the ring-shaped gears in each mode of gear train construction. These drawings are Figs. 5-6, 7-8, 13-14, 19-20, 21-22, 27-28, 33-34, 35-36.

I shall use Figs. 37 and 40 to explain the function of the gear according to the use thereof.

Then I shall explain those shown in Figs. 15-22 of the embodiments illustrated as described above, of the construction of the flat rim ring-shaped gear mechanism.

A gear rim, manufactured as shown in Figs. 17-18, has a rim part 2 thereof made to have a thickness of slightly more than m/2 (m=module i.e. pitch diameter divided by number of teeth) and, by tempering only the rim part 2 if the whole structure including teeth 3 is hardened, a high elasticity is obtained. A large backlash of 0.05–0.15m is provided in gear cutting. Quiet running can be attained if the gear ring is made with low grinding accuracy or by forging or punching for example. A retaining plate 6, of which two are required for locating—both axially and laterally—the gear ring, are bolted to a boss as shown in Figures 19, 20 and extend to the pitch circle diameter. An assembled gear wheel is shown in Figures 15, 16. The step part of the retaining ring 6, which is hardened into a disc and indicated by L.I.D.–α should measure less than m/2 in width so as to stand surface pressure and a α value, i.e. the radal clearance between hub and ring should be slightly below the backlash of the teeth. The two retaining rings are fixed to a boss part shown in Figures 21-22, leaving a clearance of α (0.02–0.05m) with the gear ring which has a width B.

The stressed configuration of the assembly is controlled by three conditions, depending on load working on the gear ring, so that quiet running can be obtained at all loads.

At no load or small load, the distortion parts of engagement (principally, eccentricity) is absorbed. This is the first function.

The second function is that, as shown in Figure 41, wherein twin engagement points of the gear ring 1 generate thrust by mutual pressing from opposite points and, therefore, the rim part 2 receives elliptical distortion. L.I.D./2, that is the length of the lever arm of received moment is larger than m so that the elastic distortion function is liable to occur at small load. The clearance C shown in Figure 41 is the limit (L.I.D.–α) of the elliptical distortion. A maximum elliptical distortion is attained when the gear ring becomes rigidly in contact with the holder. Thereafter as load increases, however, the applied stress distorts the gear ring locally at each gear tooth as shown in

Figure 12. This results in the third function namely inclination of the tooth and its centreline. Thus, misengagement caused by the non-accuracy of tooth shape is accommodated and compensated for at large loads and, therefore, the gear can continuously respond to the variation of load values.

As shown in Figure 43 at least two teeth may be inclined under load. It is generally said that the engagement of more than one tooth should be avoided. As the result of examination, however, it has been confirmed that more than two teeth are engaged.

Important herein is that, although elastic material is used in the rim part of the gear, the elasticity of teeth is substantially lost if the rim part is fixed to the boss part, for example, by shrinkage fit. Nevertheless, clearance C shown in Figure 41 becomes clearance C' so that proper elasticity distortion is obtainable.

The above is applied to the cases where the gear is used in a gear train made up as shown in Figure 37, by inserting an intermediate gear I.P.G. according to the invention between two gears in a master gear-pinion train or where the gear is used as interbediate gear I.P.G. in the inscribed and circumscribed planetary gear train shown in Figure 39.

Next, I explain the construction of the quiet gears P.G. of the gear train shown in Figures 38 and 39A.

The gear ring is suspended from the holder thereof, as shown in Figs. 11–12, to transmit rotation torque to the boss part. The gear wheels have a construction capable of achieving the required function effect without losing the above-described characteristic, as shown in Figures 1–2 or 9–10, wherein splines 4 and 5 are provided on the both sides of gear rings or on the inner circumference thereof, respectively corresponding splines 4' and 5' on the holders shown in Figures 5–6 and 13–14 respectively. The respective sets of splines engage, and are made to provide a looseness equivalent to backlash, the gear wheels provided with pitch circle diameter retaining plates 6 respectively are fixed with a boss spacer with a width $B+\alpha$ (α provides space for enabling the ring-shaped gears to move up and down) as shown in Figures 7–8 and 13–14. Thereby, eccentric absorbing function and elastic stress can be readily obtained, so that the quiet gear wheels according to the invention are capable of transmitting rotation torque to the boss part thereof. Heretofore described are the quiet gear wheels employed as circumscribed or inscribed and circumscribed intermediate gear and I.P.G. or P.G.

A gear ring is employed as an inscribed gear in the inscribed gear train as shown in Figure 40 for quite the same reason. A spline 4 is provided at the centre of the teeth on the both side ends of the rim part as shown in Figures 25–26. Alternatively splines 5 are provided on the outer circumference of the rim of the gear ring for rotation torque transmission as shown in Figures 31–32. The difference of the working thereof comes merely from the different location of the gear ring and its holder. Therefore, this embodiment is only illustrated but the working thereof is not explained. The assembly thereof is performed as shown in Figures 23–24 and 29–30 and the types of the holder and the pitch circle diameter retaining plates used herein are shown in Figures 27–28 and 33–34.

Figures 35–36 show the hardened side disc retaining plate 6 fixed on the both sides of an ordinary type gear 7 with screws. The gears perform most an effective bearing function with the quiet gears in a master gear pinion train.

WHAT I CLAIM IS:—

1. A spur gear wheel comprising a flexible gear ring mounted with limited radial, limited axial and limited circumferential clearance on a rotatable holder in a groove therein.

2. A spur gear wheel as claimed in claim 1, wherein the gear wheel incorporates a gear ring with a rim which has been treated so that the rim has a sufficient elasticity to accommodate maximum bending moment working on the teeth, the gear teeth are arranged to have a large backlash, the gear ring being held by a holding mechanism constructed so that the rotary centre of the gear ring is movable in relation with the rotary centre of the holder; the construction being such that three adjustment functions i.e. tooth inclination in the rim, elliptical deformation of the rim and eccentric rotation of the gear ring may be accommodated.

3. A spur gear as claimed in claim 1 or claim 2 when used as an intermediate gear in a master gear/pinion train.

4. A spur gear wheel as claimed in claim 1 or claim 2 when used as either gear in a two gear master gear/pinion train.

5. A quiet spur gear wheel as claimed in claim 1 or claim 2 wherein laterally extending spines are provided on both sides of the gear ring as means to transmit rotation torque in the holder.

6. A quiet spur gear wheel as claimed in claim 1 or claim 2 wherein internal splines are provided under the teeth inside the rim of the gear ring as means to transmit rotation torque to the holder.

7. A quiet spur gear as claimed in claim 1 or claim 2 for use in a planetary gear mechanism as an intermediate gear for

transmitting only revolution torque wherein faces of the gear ring opposite faces of the groove are plain.

8. A quiet spur gear as claimed in any preceding claims wherein the holder thereof includes a retaining plate.

9. A quiet spur gear as claimed in claim 1, claim 2 or claim 6 wherein the inside diameter part of the gear ring part is made plain, a plain projection is provided in both side ends of the holder, the gear ring is suspended thereon.

10. A quiet spur gear as claimed in claim 1, claim 2 or claim 6 wherein the inside diameter part of the gear rim part is made plain, a plain projection is provided on both ends of the gear ring, the gear ring is suspended on a plain holder.

11. A quiet spur gear as claimed in any preceding claim in combination with a plain gear having a hardened disc fixed on each side thereof.

12. A quiet spur gear substantially as hereinbefore described with reference to Figures 1 to 8, Figures 9 to 14, Figures 15 to 22 or Figures 29 to 34.

STEVENS, HEWLETT & PERKINS,
Chartered Patent Agents,
5 Quality Court,
Chancery Lane,
London W.C.2.

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1571628 COMPLETE SPECIFICATION
11 SHEETS *This drawing is a reproduction of the Original on a reduced scale*
Sheet 1

FIG. 1

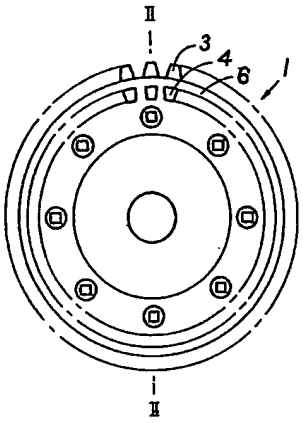


FIG. 2

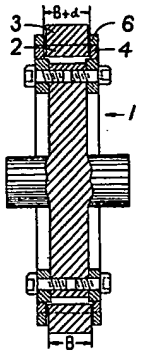


FIG. 3

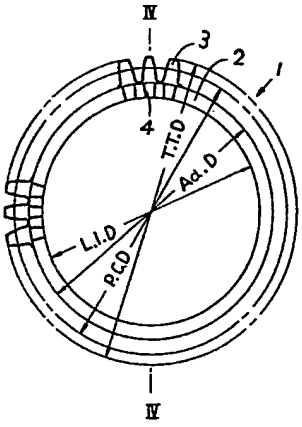


FIG. 4

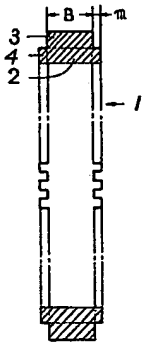


FIG. 5

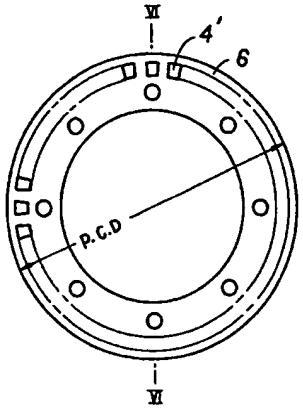


FIG. 6

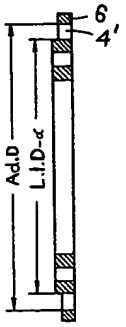


FIG. 7

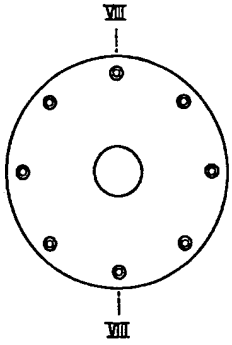


FIG. 8

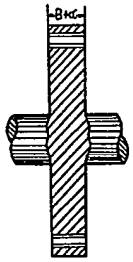


FIG. 9

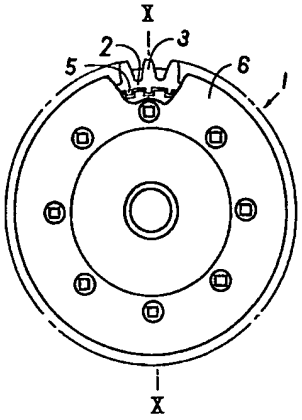


FIG. 10

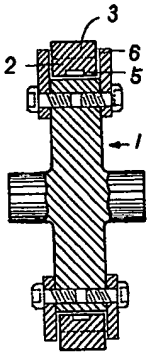


FIG. 11

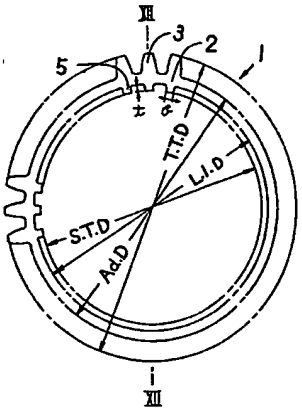


FIG. 12

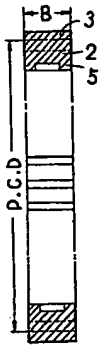


FIG. 13

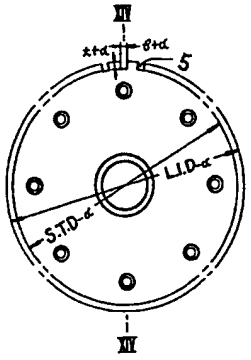


FIG. 14

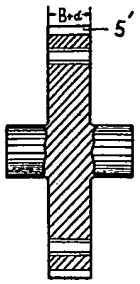


FIG. 15

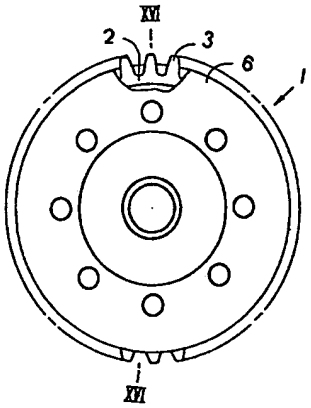


FIG. 16

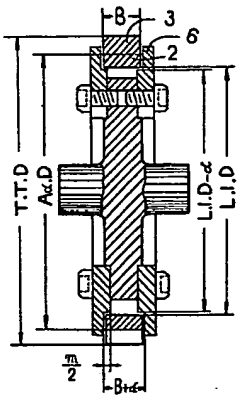


FIG. 17

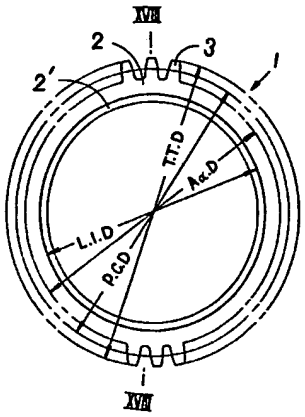


FIG. 18

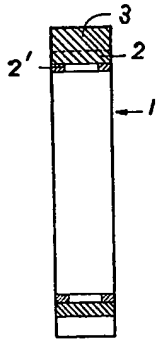


FIG. 19

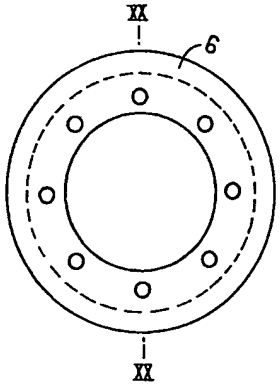


FIG. 20

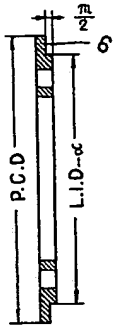


FIG. 21

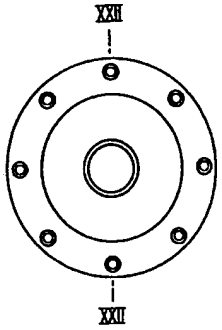
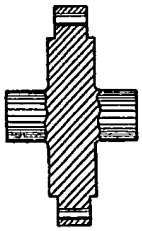


FIG. 22



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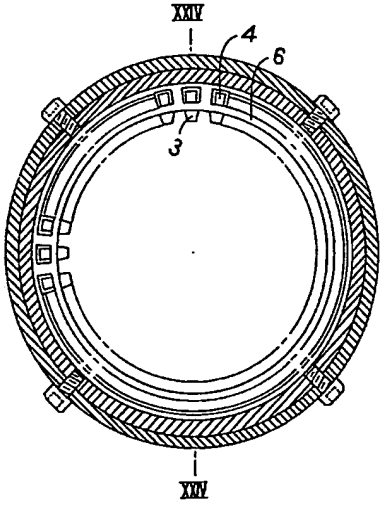


FIG. 24

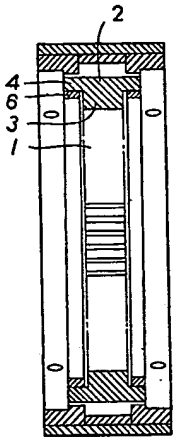


FIG. 25

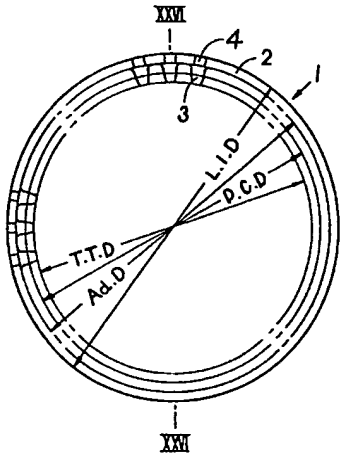
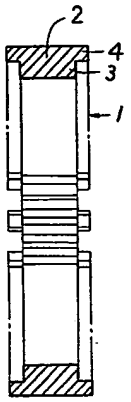


FIG. 26



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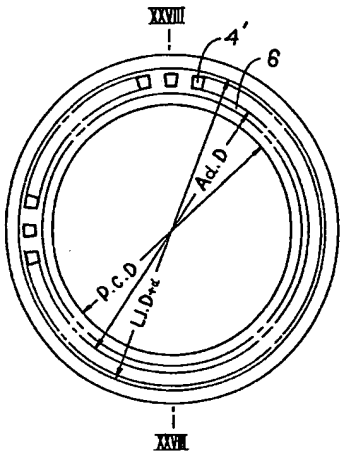


FIG. 28

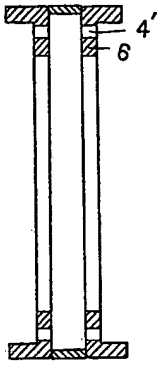


FIG. 29

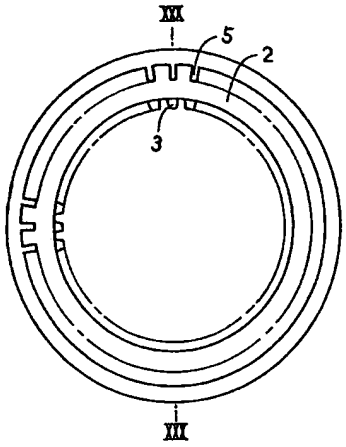


FIG. 30

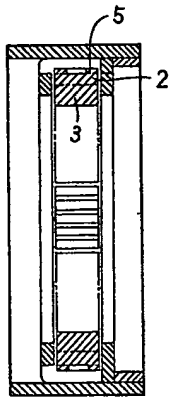


FIG. 31

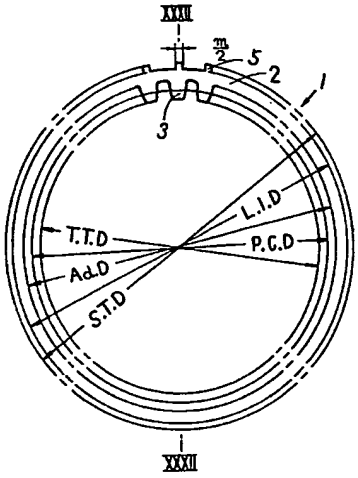


FIG. 32

FIG.33

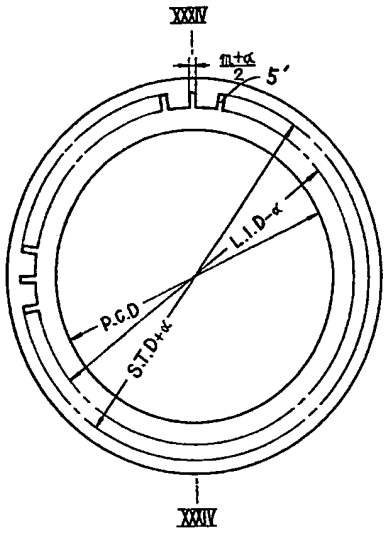


FIG.34

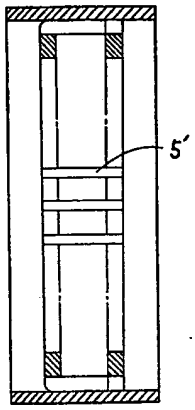


FIG.35

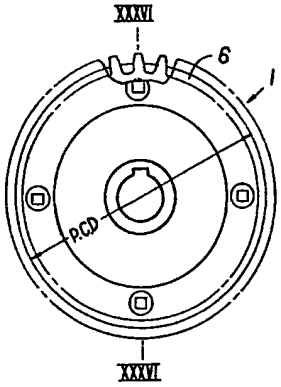
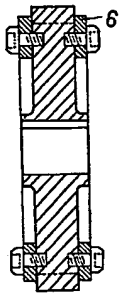


FIG.36



1571628 COMPLETE SPECIFICATION
11 SHEETS This drawing is a reproduction of the Original on a reduced scale
Sheet 10

FIG. 37

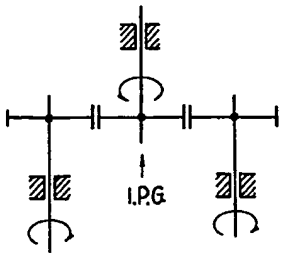


FIG. 38

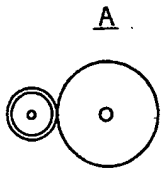


FIG. 39

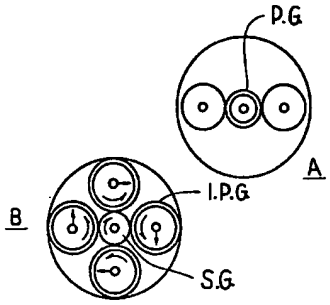


FIG. 41

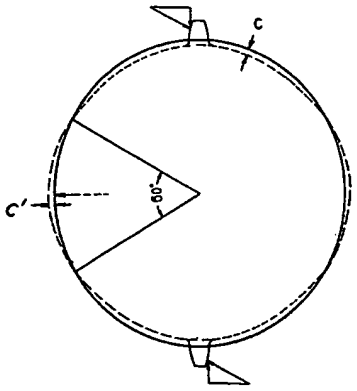


FIG. 40

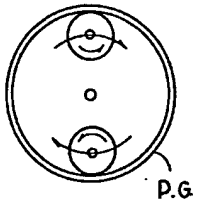


FIG. 42

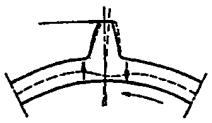


FIG. 43